

Title: "A METHOD FOR CONTROLLING AND PROTECTING ELECTRIC MOTORS,  
A SYSTEM FOR CONTROLLING ELECTRIC MOTORS AND AN ELECTRIC  
MOTOR SYSTEM"

**Disclosure of the invention**

5           The present invention is directed to a method for controlling and protecting electric motors, specially permanent magnet motors electronically actuated by a control system comprising a three-phase inverting bridge, in which it is required to monitor the position of the rotor by using a position detector physically attached to the axle or through the tension induced in the coils by the magnet, in order to  
10       correctly control actuation by the control system. The present invention is also directed to a system for controlling electric motors and an electric motor system.

          The objective of the present invention is to prevent one or more switches of the three-phase inverting bridge from being actuated at an improper time, what can lead to the generation of high currents which cannot be detected by the current  
15       detector, said currents may cause the auto-demagnetization of the rotor magnet, besides causing damages to the switches of said inverting bridge.

**Description of the State of the Art**

          The detection of the rotor position is required for the actuation of permanent magnet motors.

20           In accordance with the prior art to the present invention, such detection can be accomplished through sensors physically connected to the rotor ("hall", optical type, and the like) or by observing the voltages induced in the motor coils themselves, as described in Brazilian Patent Application PI 8805485, in such a way that the control may correctly select which phases of the motor will be activated every time.

25           As described in more details below, the control unit, when normally operating, analyzes the input of the position detector and current protection detector, thus activating the respective outputs in accordance with a predetermined table. However, if there is a failure in the position detector, it is likely that one or more switches of the three-phase inverting bridge is unduly activated, the result of which  
30       can be the generation of high currents that are not detected by the current detector, thus resulting in the auto-demagnetization of the motor magnet and damages to the switches of the three-phase inverting bridge.

          As known, the demagnetization of the magnet makes it difficult to start the

Still according to the prior art to this invention, the following measures to prevent the auto-demagnetization of the motor magnet are adopted: the design of a more robust motor, with an increased magnet thickness, what would increase notably the cost, specially in view of a larger magnet; the installation of a current protection detector in every switch or every phase of the motor, what would not only increase the cost but also the complexity of the system, by virtue of the higher number of detectors and signals for the control to analyze; or the simple elimination of the protection against auto-demagnetization, thus placing the integrity of the motor under the statistical possibility of the occurrence of a failure, what represents a serious risk not only for the system, but also for the image of the manufacturer.

After a number of investigations, it was evidenced that, when normally operating and following the same rotation direction, the sequence where the positions of the rotor are updated in the sensor is always the same. Thus, such sequence can be predetermined, whereby the control unit of the system for controlling an motor could foresee the sequence where the positions of the rotor will be changed. By knowing the speed the motor is rotating at, it is possible to foresee the time when the position of the rotor will be changed.

In accordance with the teachings of the present invention, the control unit will accept only the position foreseen for the applicable rotation direction as valid, and always at the time expected for the present speed.

The present invention has the advantages, compared to the prior art, that it is not necessary to any oversize the rotor magnet, the cost and the complexity of the motor are decreased, and the current protection detector is simplified, besides conferring a greater reliability to the system.

Such advantages are attained through a method for controlling and protecting

electric motors provided with a rotor, specially permanent magnet motors electronically actuated by a control system comprising a three-phase inverting bridge, characterized by comprising the step of counting a first period of time, during which said rotor should be between an original position and the next position, and the step of counting a second period of time that follows said the first period of time, during which said rotor should pass through said next position.

The present invention is also expressed as a system for controlling an electric motor provided with a rotor, specially a permanent magnet motor, comprising a three-phase inverted bridge and characterized by being additionally comprised of a microcontroller capable of analyzing the positions of the rotor as a function of the time, associated with a counter capable of carrying out the step of counting a first period of time, during which said rotor should be between an original position and the next position, and the step of counting a second period of time subsequent said first period of time, during which said rotor should pass through said next position, as well as an electric motor system comprising a control system, an electric motor electronically actuated by the control system, and characterized by being additionally comprised of a microcontroller capable of analyzing the positions of the rotor as a function of the time, associated with a counter capable of carrying out the step of counting a first period of time, during which said rotor should be between an original position and the next position, and the step of counting a second period of time that follows said first period of time, during which said rotor should pass through said next position.

### Brief Description of the Drawings

The present invention will be described below in more details with reference to the accompanying drawings, wherein:

Figure 1 represents a block diagram of an electric motor system electronically actuated by a control system;

Figure 2 is a schematic representation of a three-phase inverting bridge;

Figure 3 is a three-phase inverting bridge actuation table; and

Figure 4 is a generic flowchart of a method for controlling and protecting electric motors that incorporates the teachings of this invention.

### Detailed Description of the Invention

With reference to Figures 1 and 2, an electric motor system 1 is electronically actuated by a control system 2 comprising a rectifying bridge 3 basically, a capacitive

filter 4, a three-phase inverting bridge 5, a three-phase motor provided with a permanent magnet rotor 10, a control unit 11, position detectors SA, SB and SC, and a current protection detector PI.

As known in the state of the art, the control unit 11 is responsible for the monitoring of the position detectors SA, SB and SC and the current protection detector PI in order to excite, through the respective outputs, the switches T1 through T6 of the three-phase inverting bridge 5 at a suitable time in accordance with the table illustrated in Figure 3.

Thus, in response to the command of the control unit 11, the three-phase inverting bridge 5 will also apply a current to the coils of the motor 10 at the right time.

As already mentioned, in the event there is any failure in the position detectors SA, SB and SC, it is possible that one or more switches T1 through T6 of the three-phase inverting bridge 5 is not properly activated, what can generate high currents that are not detected by the current protection detector PI, resulting in the auto-demagnetization of the motor and damages to the switches T1 through T6 of the three-phase inverting bridge 5.

In accordance with the teachings of the present invention, the control system 2 also includes a microcontroller (not-shown) capable of analyzing the positions of the rotor as a function of the time, associated with a counter capable of carrying out successive steps of time counting. As known in the art, such counter may be an internal component of said microcontroller.

Said counter is set to zero whenever there is a change in the position of the rotor of the electric motor 10, the counting of a first period of time is started, during which period the rotor should be between a position and another one. Later on, the counting of a second period of time is started, during which time the rotor should pass through the next position.

In a three-phase motor with two poles there are six basic positions P1 through P6 of the rotor as shown in Figure 3, which positions should be successively reached by the rotor during a respective second period of time.

If the rotor passes through one of the positions during said first period of time, what would be too early, or after said second period of time has elapsed, what would be too late, it means that there has been some error, and then said microcontroller turns off the control system 2 in order to prevent further damages, thus preserving

the integrity of the rotor magnet and the switches of the three-phase inverting bridge.

If the rotor pass through the correct position during said second period of time, the microcontroller will issue an output updating signal and restart the counter, preparing same for counting the first and second periods of time corresponding to the  
5 next position where the rotor should pass through.

Of course, if the rotor, during said second period of time, passes through a position that is not the correct one, it also means that there has been some error, and then said microcontroller turns off the control system 2.

Figure 4 represents a generic flowchart of a method for controlling and  
10 protecting electric motors to exemplify the present invention.

In accordance with the specific teachings of this invention, said second period of time should include a tolerance for the moment the rotor passes through a given position. As an example, in a three-phase motor with two poles rotating at 3,000 rpm, the rotor takes 20 ms to complete one turn, and thus it shall consume 3.3 ms for  
15 passing through each position.

~~In order to come up with said tolerance, said second period of time measured~~  
by the counter should include a first head range of 1.65 ms ( $x/2$ ) and a second tail  
range of 6.6 ms ( $2x$ ) beyond the regular 3.3 ms, what represents a tolerance of  $x-50\%$  and  $x+100\%$ .

20 After a preferred example of realization has been described, it should be understood that the scope of the present invention encompasses other possible variations, being limited only by the contents of the appended claims including the possible equivalents.